Analytical Models for Laser-Electron Scattering Experiments Including Realistic Laser Focusing and Electron Beam Shapes

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Collisions of electrons with multi-PW optical laser beams focused on a few micrometer spot are planned in several high-end laser facilities. The goals of these experiments vary – from studying radiation reaction and electron-positron pair production to generating high-flux or high-brilliance X-rays or Gamma-rays with some degree of spatial coherence. One of the challenges that such setups face is spatial synchronisation because of the Poynting instability that can be a concern both for the interacting electron beam (if laser-generated) and the scattering laser. Another difficulty arises from the fact that a direct measurement of intense lasers at the focus is impossible. If we combine these two factors with the fact that the reproducibility between different shots is rarely achieved, the interpretation of the experimental results becomes tedious and unreliable. Even if the experiment uses a stable beam from a conventional accelerator, the plane wave approximation is too simplistic to describe the laser-electron scattering because not all particles interact with the peak laser intensity. This work takes the spatial and temporal synchronisation of the interaction into account, considers the intensity distribution of the focused Gaussian laser pulses and can be extended to arbitrary electron beam shapes. Scaling laws for pair production, previously derived for the case of a plane wave and a short electron beam [1] are extended to optimize the expected pair count for every laser facility [2]. The outlined methods are general and can be used for other purposes: to infer the achieved laser intensity at the interaction point, predict the beam divergence or energy spread after the interaction, as well as compute the expected radiation output. Tailored optimisations can be performed for any of the above parameters without resorting to full-scale particle-in-cell or Monte Carlo modelling. This fast and cost-effective approach allows for real-time support during experimental campaigns.

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References

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